SOME MONSOON PERSPECTIVES FROM AN END-USER'S POINT OF VIEW

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1. Introduction

Hong Kong, a metropolis with a population close to 7 million, is situated on the southeastern coast of China. Its weather and climate are dominated by the Asian Monsoon. Most of Hong Kong's rainfall is brought by the summer monsoon, and this rainfall is a primary source of fresh water supply in Hong Kong. Anomalous seasonal rainfall can substantially interrupt the social and economic activities of the community. For instance, tropical cyclones and rainstorms associated with the active southwest monsoon in the summer of 1999 induced 210 landslides, flooded about 700 hectares of farmland, and inflicted economic loss of approximately US$ 26 million.

On the other hand, the severe drought of 1963 caused water in Hong Kong to be rationed for four hours every four days and inflicted great hardship on the community.

Prolonged cold spells due to outbreaks of the northeast monsoon in winter pose, in Hong Kong as they do elsewhere, a health hazard especially to the elderly and the infirm. February 1996 saw minimum temperatures in Hong Kong falling to below 100C for seven days in a row, resulting in a number of cold-related deaths among the elderly.

This paper provides an overview of the research done by the Hong Kong Observatory in relation to the Asian Monsoon, and outlines the perspective of forecasters as end-users of the research.

2. Monsoon Related Research at the Hong Kong Observatory

Considerable work has been done by the Observatory on aspects of the Asian Monsoon in support of weather and short range climate forecasting activities. Studies of the winter monsoon were mainly concerned with the intensity and time of arrival of cold surges in Hong Kong for forecasting the temperature in winter and for the operation of Cold Weather Warnings as well as frost advisories. Summer monsoon studies were chiefly in association with providing aids for short range climate forecasting of Hong Kong's rainfall.

(a) Winter Monsoon

Chin (1969) surveyed the research results on the properties as well as the structure of cold surges over the south China coast, laying down the foundation for subsequent studies.

Quantitative methods for forecasting the arrival of winter surges in the winter monsoon in Hong Kong have been provided by Morrice (1973). He found that when a high pressure area developed to the west of 117°E over inland China and the maximum pressure difference between Hong Kong and any station to the south of 35°N reached 15 hPa, a northerly surge was likely to arrive in Hong Kong within 24 hours. The wind strength could be estimated by a set of regression equations based on this pressure difference. If the centre of the high pressure area passed east of 117°E, the cold air would arrive in Hong Kong in the form of an easterly surge.

Lam (1976) showed that the majority of surges arriving in Hong Kong were associated with 500 hPa troughs passing Lake Baikal, and the average time lag between the two events was about two days. Lam (1981) further identified 4 typical 500 hPa patterns preceding the cold surges. The most common pattern was a ridge-trough pair moving from west to east in the broad westerly airstream. He also found that an east-west oriented trough ahead of a blocking high at 500 hPa tended to be associated with the most intense surges.

Lai (1989) developed a forecast index based on the pressure difference between Hong Kong and Chenzhou (station 57972) to improve the forecasting of northerly surge arrival. He showed that when this pressure difference exceeded a threshold of 7-8 hPa, a cold surge could be expected in Hong Kong within the next 12-15 hours.

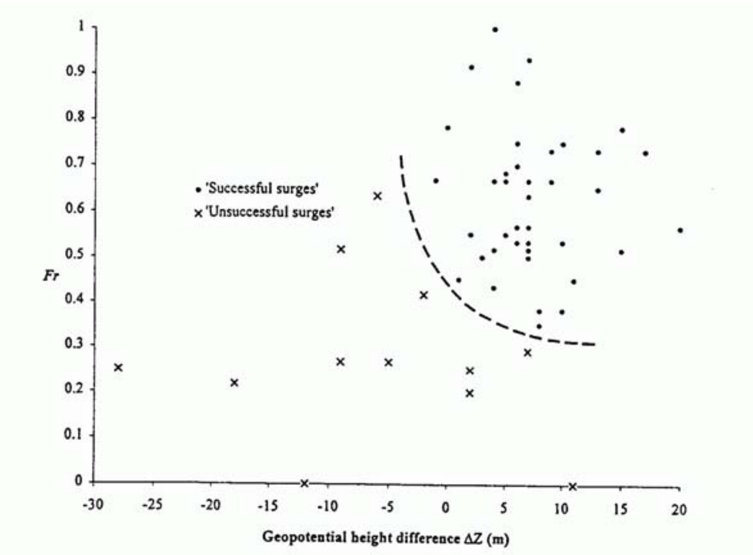

Fig. 1. Froude number (Fr) against geopotential height difference (△Z) at 850 hpa across the Nanling range.

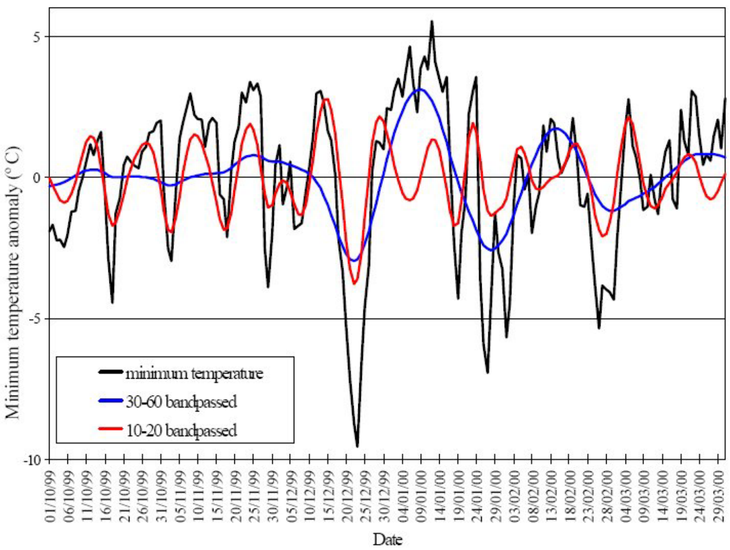

Fig. 2. Time series of the daily minimum temperature (with trend removed) recorded at the Hong Kong Observatory from October 1999 to March 2000. Minor surges were generally associated with the 10-20 day oscillation. The three most intense surges occurring at the end of December, January and February, were all related to the 30-60 day oscillation.

Chan and Lee (1997) noted that if the 850hPa geopotential height difference between Changsha and Hong Kong was large before arrival of the surge in Hong Kong, the surge was likely to be dry and vice versa.

Cheng *et al.* (1995) demonstrated the usefulness of the Froude number for forecasting the arrival of cold surges to the south China coast. Essentially, they showed that surges with Froude number exceeding 0.63 could overcome the orographic blocking of the Nanling range to the north of Hong Kong, and reach the south China coast within 24 hours. Surges with smaller Froude number would either fail to do so or required that geopotential height gradient across the Nanling range to exceed a certain threshold for the cold air to reach the south China coast (Fig. 1).

Leung and Wu (2000) observed that intense cold surges in Hong Kong were associated with 30-60 day Madden-Julian oscillations (Fig. 2). They also showed that the most intense surges were related to blocking patterns at the 500hPa level, in line with the findings of Lam (1981).

(b) Summer Monsoon

The prediction of summer rainfall in Hong Kong was first attempted by Bell (1976) who showed that that a weak monsoon in the preceding winter in Hong Kong is likely to be associated with above normal summer rainfall. In the same vein, Chang and Yeung (2003) found that the strength of the winter monsoon as represented by the Unified Monsoon Index of Lu and Chan (1999) was well correlated with annual rainfall in the ensuing year in Hong Kong (Fig. 3).

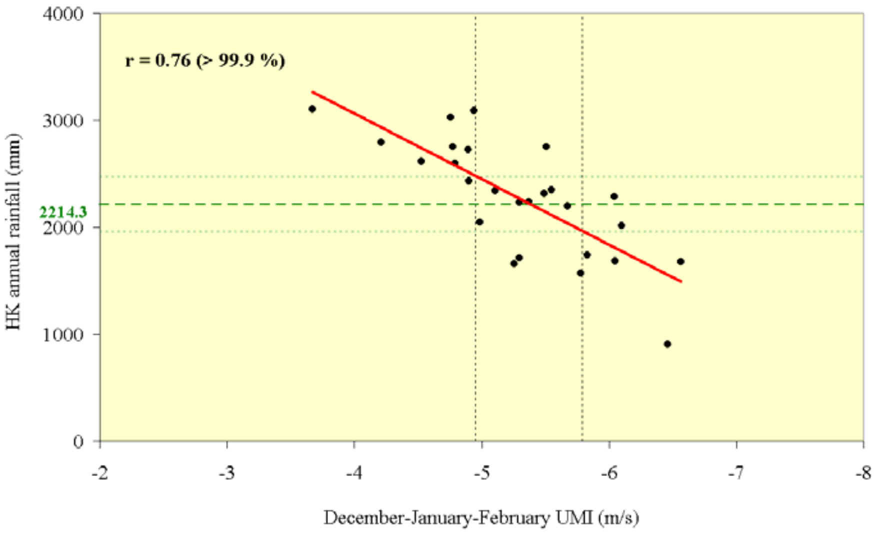

Fig. 3. Correlation between annual rainfall in Hong Kong and the winter Unified Monsoon Index (UMI). Years with strong El Niño onset, years immediately following El Niño onset, and years immediately following La Niña onset are excluded.

Onset of the summer monsoon in Hong Kong has been studied by Chan (1989). He suggested that for Hong Kong, the normal onset date is between 21 April and 10 May. If the onset date was normal, then rainfall in Hong Kong for that year was likely to be normal or above. If onset came after 20 May, above normal rainfall was unlikely.

Using data in the summer of 1998 which covered the field observation period of the South China Sea Monsoon Experiment (SCSMEX, see Lau *et al*. 2000), Chang and Wu (2001) showed the presence of 30-60 day Madden-Julian Oscillation in the outgoing longwave radiation observed over the South China Sea and 10-30 day oscillation in Hong Kong's summer rainfall (Fig. 4). The implications of such low frequency oscillations on predictability have been discussed in, for example, Jones *et al.* (2004).

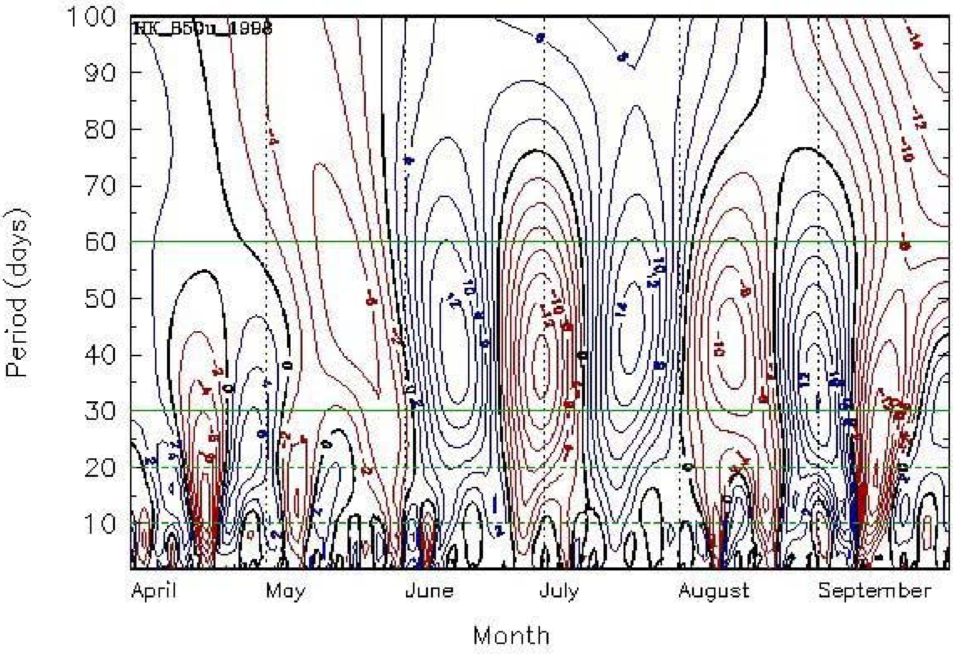

Fig. 4. Wavelet analysis of the 850 hPa zonal wind over Hong Kong in April-September 1998. The higher their absolute values the stronger are the low frequency oscillation signal. The numbers marked along the isolines are wavelet transform coefficients.

3. Forecasters' Perspective

Over the years, forecasters have benefited greatly from the immense achievements of the researchers. The latter has organized large scale international experiments such as SCSMEX in which the Observatory participated in both the field and research phases to gather intensive observations for facilitating in-depth research (Lau *et al.* 2000), advanced the understanding on monsoon in terms of its characteristics, evolution and impacts (Lau and Li 1984, Ding 1994, Chang and Chen 1995, Wu and Chan 1997, Tao and Chen 1998, Wu and Zhang 1998, Ding and Li 1999 etc.), shed light on its association with the El Nino-Southern Oscillation ENSO and how the resulting variability affected weather and climate (Klein *et al.* 1999, Chang *et al*. 2000a, Lau and Nath 2000, Wang *et al.* 2000, Huang 2001, Lau and Wu 2001, Molteni *et al.* 2003 among others), developed schematics to aid users visualize the interactive processes between the winter and summer monsoons leading to the tropospheric biennial oscillation (TBO) (Chang *et al.* 2000b, Chang and Li 2000).

However, from the perspective of Hong Kong Observatory forecasters, consensus has yet to be reached in a few aspects of the monsoon, which if resolved will provide a common communicating platform for researchers and forecasters. These are:

(a) Monsoon terminology – Indian Monsoon, South Asian Monsoon, East Asian Monsoon, South China Sea Monsoon, South East Asian Monsoon, Western North Pacific Monsoon, Asian Pacific Monsoon are some of the terminology that have been used in the literature, not always meaning the same thing. Wang and Lin (2002) have proposed a delineation of the Indian Summer Monsoon, East Asian Summer Monsoon and Western North Pacific Summer Monsoon sub-regions but the use is not widespread. It would be useful if a standard terminology of the monsoon regions could be arrived at to facilitate communication and understanding.

(b) <u>Monsoon index</u> – Several indices have been suggested for the strength of the monsoon but none is widely accepted. Examples of the various indices proposed in the literature include the Circulation Index of Webster and Yang (1992), Convection Index of Wang and Fan (1999), the Unified Monsoon Index of Lu and Chan (1999) for South China, the EAP (East Asia/Pacific) Index of Huang (2004), the Dynamical Normalized Seasonality Index of Li and Zeng (2003). Standardization of monsoon indices as well as monsoon onset and retreat indices (see for example, Zeng and Lu 2004, Wang *et al*. 2004) would greatly facilitate inter-comparison of results of research or forecasts. It would also minimize the chance of results relevant only to one monsoon region being unwittingly applied to another by forecasters.

(c) <u>Monsoon onset and strength forecasts</u> – The time of monsoon onset and the strength of the monsoon are important factors in short range climate forecasting. Forecasts of these factors if achievable and made widely available in the future would be very useful for seasonal or short rage climate forecasting by meteorological services. For example, a regression equation could be set up between past monsoon indices as predictors and past rainfall as predictands. Forecasts of rainfall for the coming season could then be made from predicted monsoon indices. An analogy for these monsoon forecasts is the sea surface temperature anomaly (SSTA) forecasts made available on the Internet by a number of climate centers and widely used for the seasonal forecasts of climate variables (Goddard *et al*. 2001).

(d) <u>Monsoon embedded meso-scale disturbances</u> - Meso-scale convective systems are often embedded in the summer monsoon, bringing severe weather (see, for example Wang 2004). Occasionally midget tropical cyclones form in monsoon gyres. These midget tropical cyclones pose a challenge for forecasters as they are small in size, have a short lifespan and are hard to detect (Lander 1994, 2000).

One such midget tropical depression developed from a meso-scale cloud cluster (MCC) associated with an area of low pressure and affected Hong Kong in the evening 18 June 2000 (see Leung *et al*. 2000). A satellite imagery showing the cloud bands just before cyclogenesis is shown in Fig. 5a, and the corresponding synoptic pattern is shown in Fig. 5b. The midget tropical depression formed very close to land, and in consideration of public safety in Hong Kong the local Strong Wind Signal No. 3 was hoisted directly without the Standby Signal being hoisted first. This case points to the importance of having at hand techniques for the early recognition and diagnosis of potential intensification of MCCs embedded in monsoon systems so that advance warning can be given to the public if necessary and at the first opportunity. Perhaps a tool for estimating convection intensity in MCCs akin to the Dvorak technique for tropical cyclone intensity could be attempted.

4. Conclusions

The Hong Kong Observatory has carried out considerable research work on some aspects of the Asian Monsoons to support its forecasting operations, contributed to international experiments such as SCSMEX, and benefited from the great strides in knowledge generated by the research community.

Standardization of terminologies in respect of monsoon regions, onset, and strength remains issues that await consensus and will require the concerted effort of the meteorological community. Forecasts of monsoon onset and strength will help short range climate forecasting.

Better capability for identification of the abrupt development of meso-scale disturbances embedded in the summer monsoon will be useful for operational forecasting of severe weather and enhancing public safety.

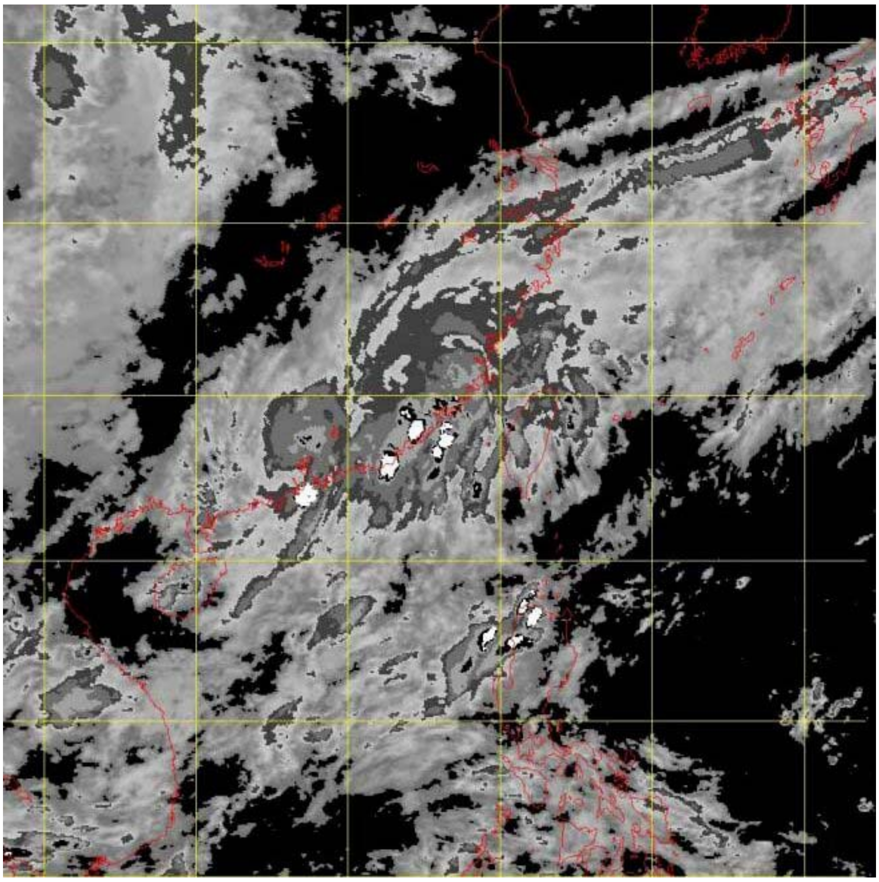

Fig. 5a. Enhanced infra-red satellite imagery of the Meso-scale Cloud Cluster at around 1230 UTC (8:30 p.m. local time) on 18 June 2000. The imagery is from GMS-5.

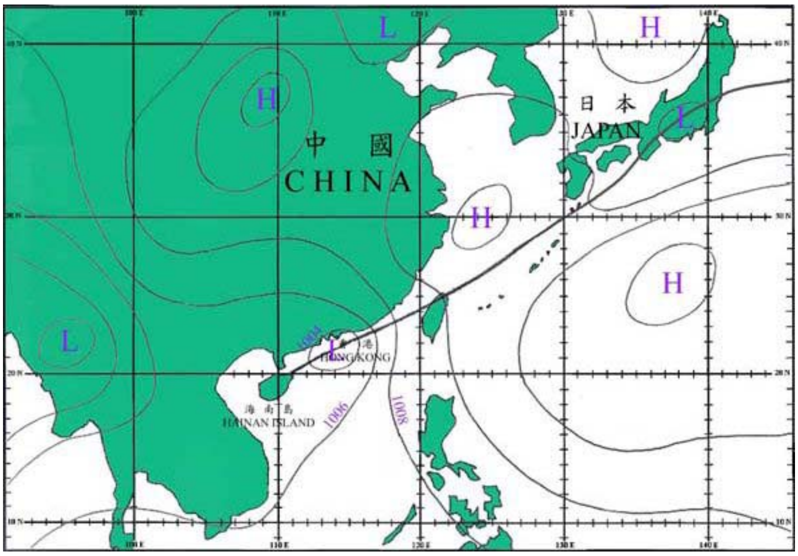

Fig. 5b. Surface weather chart at 1200 UTC (8:00 p.m. local time) on 18 June 2000.

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